10/580,209

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 236 434 B1**

(12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication of patent specification: **25.10.95 Bulletin 95/43**

(51) Int. Cl.^{6}: **G01N 22/00**

(21) Application number: **86905585.5**

(22) Date of filing: **02.09.86**

(86) International application number: **PCT/US86/01776**

(87) International publication number: **WO 87/01455 12.03.87 Gazette 87/06**

(54) WAVE SHAPE CHEMICAL ANALYSIS APPARATUS AND METHOD.

(30) Priority: **09.09.85 US 774150**

(43) Date of publication of application: **16.09.87 Bulletin 87/38**

(45) Publication of the grant of the patent: **25.10.95 Bulletin 95/43**

(84) Designated Contracting States: **AT BE CH DE FR GB IT LI LU NL SE**

(56) References cited:
US-A- 3 626 284
US-A- 3 648 513
US-A- 3 654 072
US-A- 3 765 841
US-A- 3 789 655
US-A- 4 327 587

(56) References cited:
A. Kraszewski et al.: "An Improved Microwave Method of Moisture Content Measurement and Control", IEEE Transactions on Industrial Electronics and Control Instrumentation, vol. IECI-23, No.4, Nov.1976, p.364-370, New York, US

(73) Proprietor: **SOLID STATE FARMS, INC.
500 Winchester Drive
Reno, NV 89506 (US)**

(72) Inventor: **Fuller, Milton Earl
500 Winchester Drive
Reno, Nevada 89506 (US)**
Inventor: **Fletcher, Gary S.
12683 Princeton Drive
Auburn, California 95603 (US)**

(74) Representative: **BROOKES & MARTIN
High Holborn House
52/54 High Holborn
London, WC1V 6SE (GB)**

Jouve, 18, rue Saint-Denis, 75001 PARIS

Description

This invention relates generally to chemical analysis apparatus and method for determining chemical concentration of a substance based on a technique of waveform distortion analysis.

The public awareness of the health hazards that sodium compounds including table salt pose in food products has increased dramatically in recent years. There are a number of apparatus currently available that are capable of performing chemical analyses using a variety of techniques to measure concentrations of chemical substances such as sodium. These techniques include mass spectrophotometry, nuclear resonance, flame photometry, specific electrodes, conductivity testers, and refractometry. Unfortunately, the accuracy of these currently available apparatus is strongly dependent upon their cost. At the low end of the cost scale is the conductivity tester, which measures the conductivity of a test sample to determine sodium content. Unfortunately, a conductivity tester will yield inaccurately high test results when the test sample contains other conductive substances such as vinegar. What is needed is an inexpensive, but accurate, sodium measurement apparatus.

On a broader scale there is a need for a chemical analysis apparatus that is accurate, easy to use, and inexpensive, and that responds rapidly to changes in chemical concentrations. A few of the many approaches to chemical analysis apparatus are described in the following US Patents: 3,048,772, issued August 7, 1962 to R.K. Saunders, et al, entitled " Process for Conducting Quantitative Analysis", which discloses a nuclear magnetic resonance spectrometer; 3,287,638, issued November 22, 1966 to V.W. Bolie, entitled "Method of Counting Erythrocytes Utilizing High Frequency Current", which measures impedance variation of a solution flowing through an orifice to count red blood cells; 3,489,522, issued January 13, 1979 to H.M. McConnell, entitled "Electron Spin Resonance Labeling of Biomolecules", which utilizes a radio frequency alternating magnetic field and a unidirectional magnetic field to identify biomolecules; and 3,765,841, issued October 16, 1973 to Paulson, et al, entitled "Method and Apparatus for Chemical Analysis", which measures the rate of change of the conductivity of a test sample having two chemicals to measure the concentration of one chemical which is formed at a rate which is proportional to the quantity of the other. Chemical analysis apparatus such as these are either very expensive, or very limited in their use.

It is also known to measure the moisture content of granular materials, such as sand, by measurement of the attenuation and phase shift of an electromagnetic wave passing through the sample. Thus, in IEEE Transactions on Industrial Electronics and Control Instrumentation, vol. IECI-23, No 4, November, 1976, pp. 364-370, and apparatus and method are described in which a radio frequency carrier and a microwave frequency subcarrier are used to measure dielectric constant of the sample. The transmitted combined signal is received and separated into its carrier frequency and subcarrier frequency components and amplitude attenuation of the carrier and phase shift of the sub-carrier are measured.

According to the invention there is provided an apparatus as defined in claim 1.

Further according to the invention there is provided a method as defined in claim 20.

The apparatus and method of the present invention are not based upon conventional conductivity testing techniques or any of the other previously employed chemical analysis techniques, such as conventional dielectric or permittivity measurements. Instead, a comparative analysis of the change in shape of the periodic signal transmitted through a test sample is made. The signal is distorted or otherwise transformed by one or more chemical substances in the test sample. The waveform shape and frequency are selected so that the transformation is particularly responsive to the presence of a selected chemical substance, so that the magnitude of distortion or transformation of the signal is directly related to the concentration of the selected chemical substance.

In the preferred embodiment of the invention, which measures the concentration of salt in an aqueous solution, the waveform generator generates a square wave at a frequency of either sixteen or eighteen megahertz, and supplies that signal to the antenna probe. The antenna probe includes two conductive prongs protruding in parallel from a housing. The prongs act as antennas for transmitting the square wave signal into the test sample and for receiving the distorted signal from the test sample. In use, the prongs of the antenna probe are inserted into the test sample, and the square wave signal is transmitted into the test sample via one of the prongs. The waveform shape of the signal is distorted by the sodium or chloride ions as the signal propagates through the test sample. The distorted signal is received by the other prong of the antenna probe and is sent to the detector circuit for analysis.

The detector circuit responds to the transmitted and received signals to generate an output signal that is related to the magnitude of the distortion of the signal. A capacitor and resistor network supplies an "average" of the transmitted and received signals as a reference signal to a common input terminal of an analog multiplier. The analog multiplier multiplies the difference between the transmitted and referenced signals by the difference between the received and reference signals to generate the output signal. An output device responds to the output signal of the detector circuit to visually indicate the presence and concentration of salt in the test

sample.

The features and advantages described in the specification are not all inclusive, and particularly, many additional features and advantages will be apparent to one of ordinary skill in the art in view of the drawings, specification, and claims hereof. Moreover, it should be noted that the language used in the specification has been principally selected for readability and instructional purposes, and may not have been selected to delineate or circumscribe the inventive subject matter, resort to the claims being necessary to determine such inventive subject matter.

BRIEF DESCRIPTION OF THE DRAWING

Figure 1 is a block diagram of a chemical analysis apparatus according to the present invention.

Figure 2 is a sectional view of an antenna probe utilized in the chemical analysis apparatus of Figure 1.

Figure 3 is a schematic view of an electronic circuit utilized in the chemical analysis apparatus of Figure 1 for signal generation and distortion detection.

Figure 4 is a schematic view of an output circuit utilized in the chemical analysis apparatus of Figure 1.

Figure 5 is a voltage curve for output from the analog multiplier of the apparatus of the present invention.

BEST MODE OF CARRYING OUT THE INVENTION

Figures 1 through 4 of the drawings depict the preferred embodiment of the present invention for purposes of illustration only. One skilled in the art will readily recognize from the following discussion that alternative embodiments of the structures and methods illustrated herein may be employed without departing from the principles of the invention as defined in the claims.

The preferred embodiment of the present invention is an apparatus and method for determining the concentration of sodium chloride in an aqueous solution based on waveform distortion analysis. As illustrated more generally in Figure 1, the chemical analysis apparatus 10 of the present invention includes a waveform generator 12, a transmitting antenna 14, a receiving antenna 16, a detection circuit 18, and an output device 20. The transmitting and receiving antenna 14 and 16 are placed in contact with a test sample 22, which contains a solution to be tested for the presence of one or more selected chemical substances.

In operation, the waveform generator 12 supplies a signal having a periodic waveform to the transmitting antenna 14 and to the detection circuit 18. The signal 23 is transmitted into the test sample 22, propagates through the test sample, and is received by the receiving antenna 16. The waveform shape and frequency of the signal 23 is selected to be susceptible to distortion by the presence of the selected chemical in the test sample. As the signal 23 propagates from the transmitting antenna 14 to the receiving antenna 16, the signal is distorted by the selected chemical substance. The amount of the distortion is a function of the concentration of the selected chemical in the test sample 22. Both the undistorted transmitted signal and the distorted received signal are supplied to the detection circuit 18, which analyses the two signals to determine the magnitude of the distortion, and generates an output signal based on that analysis. The output signal is supplied to the output device 20, which visually displays the measured concentration of the selected chemical.

Figures 2, 3, and 4 illustrate the preferred embodiment of the chemical analysis apparatus 10, which is intended for measuring the concentration of sodium or chloride ions in an aqueous solution. Figure 2 shows an antenna probe 24 that contains the transmitting and receiving antennas 14 and 16. Each antenna 14 and 16 is a conductive, cylindrical rod 26 extending outwardly from an insulative housing 28. At the inward end of each rod 26 is an axial cavity 30, into which is soldered a wire 32 that electrically connects the rod 26 to either the waveform generator 12 or the detection circuit 18. The axial cavity serves as a filter to help eliminate unwanted or unused harmonics of the transmitted and received signals. The outward tips of the rods 26 are fully radiused.

In Figure 3, the circuitry of the detection circuit 18 is illustrated. The heart of the detection circuit 18 is an analog multiplier 34, which receives the transmitted and received signals as input signals and generates an output signal that is related to the amount of distortion in the signal caused by sodium or chloride ions in the test sample. In the preferred embodiment, the waveform generator 12 is a square wave generator 36, which is coupled to a Y input terminal of the analog multiplier 34 through a capacitor 38, and is coupled to the transmitting antenna 14 of the antenna probe 24 through a capacitor 40. The receiving antenna 16 of the antenna probe 24 is coupled to an X input terminal of the analog multiplier 34 through a capacitor 42. Capacitors 40 and 42 isolate the antenna probe from any direct current components of the signal 23.

A capacitor and resistor network acts as a summing circuit to supply an "average" of the transmitted and received signals to a common input terminal of the analog multiplier 34 for use as a reference signal. The capacitor and resistor network includes a resistor 44 connected between the Y input terminal and a grounded

node 46, a resistor 48 connected between the X input terminal and the grounded node 46, and a resistor 50 and a capacitor 52 connected in parallel between the common input terminal and the grounded node 46.

The analog multiplier 34 in effect measures the amount of distortion between the transmitted and received signals, which is directly related to the concentration of sodium or chloride ions in the test sample 22. The analog multiplier 34 multiplies the differential voltage applied across the X input and common terminals by the differential voltage applied across the Y input and common terminals. Since the reference signal supplied by the capacitor and resistor network is intermediate in voltage between the transmitted and received signals, one differential input to the analog multiplier 34 is positive and the other is negative. Thus, the X times Y product output signal is inversely related to the difference between the transmitted and received signals, and is, thus, inversely related to the concentration of sodium or chloride ions in the test sample 22.

The output signal of the analog multiplier 34 is conditioned and then supplied to the output device 20. A capacitor 54 smooths the pulses and irregularities in the output signal of the analog multiplier 34 to supply a stable, direct current signal to a buffer 56. The output terminal of the buffer 56 is coupled to ground through a resistor 58 and to the inverting input terminal of an operational amplifier 60 through another resistor 62. The operational amplifier 60 is configured as an inverting amplifier with a reference voltage, Vref, supplied to its non-inverting input terminal, and a resistor 64 coupled to feedback the output, Vout, to the inverting input terminal. Since the operational amplifier 60 is configured as an inverting amplifier, the output signal of the operational amplifier 60, Vout, is directly related to the concentration of sodium or chloride ions in the test sample 22.

As shown in Figure 4, the output device 20 receives the output signal of the operational amplifier 60, Vout, and, if the measured concentration of sodium or chloride ions is high enough, activates one of five light emitting diodes 66. The output device 20 includes a non-inverting operational amplifier 68, and five operational amplifiers 70 configured as comparators. An adjustable resistor 72 is connected to feedback the output of the operational amplifier 68 to its inverting input terminal, which also is coupled to ground through a resistor 74. The output signal of the detection circuit 18, Vout, is supplied to the non-inverting input terminal of the operational amplifier 68. The output terminal of the operational amplifier 68 is connected to the inverting input terminals of the five comparator operational amplifiers 70. A resistor ladder 76 consisting of six resistors 78, 80, 82, 84, 86, and 88 is coupled between a supply voltage, Vs, and ground. Each of the five internal nodes of the resistor ladder 76 is connected to the non-inverting input terminal of one of the comparator operational amplifiers 70. Resistors 90, 92, 94, 96, and 98 are connected as feedback resistors between the output terminal of each comparator operational amplifier 70 and its non-inverting input terminal. A resistor and diode ladder 100 consisting of six resistors 102, 104, 106, 108, 110, and 112 and six diodes 66 and 114 is coupled between the supply voltage and ground. Each of the five internal nodes of the resistor and diode ladder 100 is connected to the output terminal of one of the comparator operational amplifiers 70. The output terminals of four of the comparator operational amplifiers 70 are coupled to the supply voltage via pull-up resistors 116, 118, 120, and 122, respectively.

The output signal of operational amplifier 68 acts in cooperation with the resistor ladder 76 and the comparator operational amplifiers 70 to turn on the appropriate light emitting diode (LED) 66. Assume, for example, that the output voltage of the operational amplifier 68 is less than the voltage at the node between resistors 80 and 82, but greater than the voltage at the node between resistors 82 and 84. This will cause the upper two comparator operational amplifiers 70 to supply positive output voltages, while causing the lower three comparator operational amplifiers 70 to supply negative output voltages. Current will flow through resistor 106, causing the middle LED 66 to light. The other LED's 66 will not light because no current will flow through resistors 102, 104, 108, and 110.

OPERATION

In order to tune the sensitivity of the apparatus to a selected chemical, the waveform shape and frequency of the transmitted signal are selected so that the distortion of the signal is particularly responsive to the presence of the selected chemical. Since it is difficult to predict how various chemical substances will respond, the selection process is largely empirical. The first step in the selection process is to determine at which frequencies a chemical substance causes a maximum amount of distortion in a square wave signal. The antenna probe is inserted into a test sample containing a representative amount of the selected chemical substance. Then, the distortion of the square wave signal is monitored while varying the frequency of the square wave signal through a range of frequencies somewhere between ten and one hundred megahertz. The distortion can be monitored by examining the output signal of the analog multiplier, or by displaying the Lissajous patterns of the analog multiplier differential input signals on a oscilloscope and looking for distorted patterns.

Most likely, several frequencies will produce a peak in the magnitude of the distortion of the square wave

signal. It is advantageous to repeat the above process for several of the chemical substances most likely to be found in test samples in company with the selected chemical substance. Some of the frequency peaks of the companion substances may approach or coincide with some of the frequency peaks of the selected substance. By choosing an isolated frequency peak of the selected substance, interference and false readings due to the companion substances will not occur. It has been found that square wave signals at frequencies of about sixteen and eighteen megahertz are good choices for the measurement of concentrations of sodium chloride in an aqueous solution.

Once a frequency is determined, the waveform shape of the transmitted signal can be varied to investigate whether other waveforms are more susceptible to distortion by the chemical substance. Combinations of multiple signals with different frequencies and waveforms can also be investigated. The goal is to select a signal that is distorted by the presence of the selected chemical substance, but is not distorted by the presence of companion chemical substances that may be in the test sample in actual operation.

In addition to selecting the waveform shape and frequency of the transmitted signal, the component values of the capacitor and resistor network are also selected to tune the sensitivity of the apparatus to the selected chemical. This selection process is also empirical, and should be coordinated with the selection of the transmittal signal. Again, the distortion can be monitored by examining the output signal of the analog multiplier, or by displaying the Lissajous patterns of the analog multiplier differential input signals on an oscilloscope and looking for distorted patterns.

The following table lists the component values of the capacitors and resistors employed in apparatus constructed in accordance with the present invention and used to measure the concentration of sodium chloride:

capacitors 38, 40, 42	0.01 microforad
resistor 44	2000 ohm
resistor 50	1000 ohm
capacitor 52	0.68 microfarad
capacitor 54	2.2 microfarad
resistor 58	5100 ohm
resistor 62, 64	100,000 ohm
resistor 72	5000 ohm, variable
resistor 74	1000 ohm
resistor 78	22,000 ohm
resistor 80	4700 ohm
resistor 82	8200 ohm
resistor 84	12,000 ohm
resistor 86	8200 ohm
resistor 88	24,000 ohm
resistor 90, 92, 94, 96, 98	470,000 ohm
resistor 102	470 ohm
resistor 104	820 ohm
resistor 106, 108, 110, 112	470 ohm
resistor 116, 118, 120, 112	10,000 ohm

The distance between antennas 14 and 16 was sent at 0.80 inches. The areas of antennas were too small to reliably calculate the spacing which would produce the best efficiency, but signal peaks were observed at several spacings as the antennas were separated. The selected spacing was believed to be a fractional multiple of the transmission frequency which would enhance efficiency, although other spacings are acceptable in connection with the apparatus and method of the present invention.

Figure 5 illustrates the output voltage, measured between the X times Y product output signal and the reference voltage, V_{REF}, as the concentration of sodium is increased in 100 milliliters of water. As will be seen, the curve would essentially be a straight line if plotted on a logarithmic scale. It was found that extremely high reproduceability could be achieved in connection with these data, making it possible to accurately detect the presence of Na and its concentration in milligrams per 100 milliliters of solution.

The curve of Figure 5 was generated by employing a transmitted signal of 16 megahertz. The greatest sensitivity to distortion for chloride ions was found by testing sodium chloride and potassium chloride to occur at 17.75 megahertz. This was determined by the empirical techniques set forth above. Sodium chloride also will distort by the transmitted square wave signal at about 18 megahertz, and 42.50 megahertz. The 17.75 megahertz frequency is somewhat better than 16 megahertz. Use of 17.75 megahertz has the advantage of being somewhat sensitive to the common table salt substitute, potassium chloride. Since transmitting a signal of 17.75 megahertz requires a custom transmitter, a signal of 18.00 megahertz can be used in commercial, economically priced "salt meter." As will be apparent it would be possible to use paired oscillators for greater

selectivity as to the ion being sensed.

The sodium chloride detector also was used with vinegar, sugar, alcohol and various starch solutions and produced outputs indicating that there was no sodium chloride present. It did not, therefore, give false positive readings in such solutions, including heavily ionized solutions.

When mixtures of sodium chloride and vinegar, sugar, starch, etc. were measured, the apparatus of the present invention could sense the presence and accurately measure the concentration of sodium chloride in such solutions.

Using the method of the present invention, sensitive transmission frequencies were also obtained for potassium chloride, sugar, alcohol, water and vinegar. The component values of the capacitors and resistors for the sodium chloride detector remained the same, and the following distortion sensitive transmission frequencies were found:

Compound	Megahertz
Potassium chloride	17.75, 35.70
Sugar	44.3, 44.6, 50.0
Vodka	16.62, 35.5, 35.95
Water	19.80, 32.05, 36.31, 35.6, 44.3, 50.0
Vinegar	20.4

Further refinement and selectivity with respect to these compounds is believed possible by adjusting the wave form and/or the resistance and capacitance of the circuit.

As will be apparent, therefore, the apparatus of the present invention also appears to be well suited for computer implementation to perform complex chemical analysis. A rapid series of signals at selected frequencies can be transmitted with corresponding circuit variations, if required, to enable a high degree of selectivity and a large range of chemical compounds to be sensed, measured, stored and then output using the apparatus of the present invention and a microprocessor controller.

From the above description, it will be apparent that the invention disclosed herein provides a novel and advantageous apparatus and method for determining chemical concentration based on waveform distortion analysis. The foregoing discussion discloses and describes merely exemplary methods and embodiments of the present invention. One skilled in the art will readily recognize from such discussion that various changes, modifications and variations may be made therein without departing from the scope of the invention. Accordingly, the disclosure of the present invention is intended to be illustrative, but not limiting, of the scope of the invention, which is set forth in the following claims.

Claims

1. An apparatus for measuring the concentration of a chemical in a test sample, said apparatus comprising:
waveform generation means for generating an ac-signal having a periodic nonsinusoidal waveform
a first antenna probe ac-coupled to said waveform generation means for transmitting said signal as an electromagnetic signal into the test sample
a second antenna probe for receiving a corresponding periodic electromagnetic signal from the test sample spaced apart from the first antenna probe
detection means which is ac-coupled to the second antenna probe in order to detect the received signal, which is ac-coupled to the waveform generation means in order to detect the signal as transmitted, and which quantifies the distortion of the waveform shape of said received signal with respect to the waveform shape of said generated ac-signal, wherein the magnitude of the distortion is related to the concentration of the chemical in the test sample.

2. An apparatus as claimed in claim 1, characterised in that said detector (18) further correlates the quantified distortion with a concentration of the chemical in the sample.

3. An apparatus as claimed in claim 2, characterised in that said input signal has a substantially square waveform.

4. An apparatus as claimed in claim 1, characterised in that said detector (18) is formed to sense an output signal having a plurality of simultaneously present frequencies and compares said output signal to said input signal without separating said output signal into its component frequencies.

5. An apparatus as claimed in claim 2, characterised in that said generator (12) generates an input signal having a frequency of between fifteen and nineteen megahertz.

6. An apparatus as claimed in claim 5, characterised in that said input signal has a frequency substantially equal to sixteen megahertz.

7. An apparatus as claimed in claim 5, characterised in that said input signal has a frequency substantially equal to eighteen megahertz.

8. An apparatus as claimed in claim 1, characterised in that said two antenna probes include two conductive prongs (14, 16) protruding from a housing, wherein one of said prongs is operable for coupling said input signal with the test sample and the other one of said prongs is operable for coupling of said probe to said test sample for receipt of said output signal from the test sample.

9. An apparatus as claimed in claim 8, characterised in that said prongs (14, 16) are formed for insertion to said test sample for coupling thereto and are disposed substantially in parallel.

10. An apparatus as claimed in claim 9, characterised in that each of said prongs is generally cylindrical in shape and includes a solid end (26) that protrudes from said housing, said prongs further being formed with a hollow cavity (30) disposed opposite said solid end for receiving an electrical conductor (32) for connection to said waveform generator and said detector.

11. An apparatus as claimed in claim 8, characterised in that the tip of said solid end of each of said prongs is fully radiused.

12. An apparatus as claimed in claim 1, characterised in that said detector includes a summing device (44, 48, 50, 52) for generating a reference signal having a periodic waveform by combining said input signal and said output signal, and said detector (18) includes a signal processor (20) coupled to receive said input signal, said output signal, and said reference signal for generating a signal related to the concentration of the chemical in the test sample by multiplying the voltage differential between said input signal and said reference signal by the voltage differential between said output signal and said reference signal.

13. An apparatus as claimed in claim 12, characterised in that said summing device includes a capacitor (52) and resistor network (44, 48, 50) coupled to receive said input signal and said output signal.

14. An apparatus as claimed in claim 13, characterised in that said input signal is supplied to a first terminal of said signal processor and to said capacitor and resistor network from said waveform generator, and wherein said output signal is supplied to a second terminal of said signal processor and to said capacitor and resistor network from said second antenna probe.

15. An apparatus as claimed in claim 14, characterised in that said capacitor and resistor network includes a first resistor (44) coupled between said first terminal (Y input) of said signal processor and a grounded node (46), a second resistor (48) coupled between said second terminal (X input) of said signal processor and said grounded note, and a third resistor (50) and a capacitor (52) coupled in parallel between said grounded node and a third terminal (common) of said signal processor.

16. An apparatus as claimed in claim 15, characterised in that said signal processor includes an analog multiplier (34) that forms the product of the voltage applied across said first and third terminals and the voltage applied across said second and third terminals, and includes a capacitor (54) coupled between an output terminal of said analog multiplier and ground, whereby said output terminal generates a direct current signal that is related to the concentration of the chemical in the test sample.

17. An apparatus as claimed in claim 12, characterised in that said detector- further includes an output responsive to said signal related to the concentration of the chemical for displaying an indication of the concentration of the chemical in the test sample.

18. An apparatus as claimed in claim 1, characterised in that said waveform generator (36) is isolated from said first antenna probe by a capacitor (40) to prevent direct current flow through the test sample.

19. An apparatus as claimed in claim 1, characterised in that said detector is isolated from said second antenna probe by a capacitor (42) to prevent direct current flow through the test sample.

20. A method for measuring the concentration of a chemical in a test sample, said method comprising the steps of:
generating an <u>ac</u>-signal having a periodic <u>nonsinusoidal</u> waveform
transmitting said signal as an electromagnetic signal into the test sample <u>by means of a first antenna</u> probe
receiving a corresponding electromagnetic signal from the test sample <u>by means of a second antenna probe spaced apart from the first antenna</u> probe
detecting the received signal and also the <u>generated ac-signal</u> and quantifying the <u>distortion</u> of the waveform shape of said received signal with respect to the waveform shape of said <u>generated ac-signal</u>, whereby the magnitude of the <u>distortion</u> is related to the concentration of the chemical in the test sample.

21. A method as claimed in claim 20, characterised in that prior to said step of transmitting an electromagnetic signal, an electromagnetic signal is generated having a shape and frequency selected with reference to the chemical to be measured in order to enhance the magnitude of the distortion and said signal is used during said transmitting step.

22. A method as claimed in claim 20, characterised in that said step of transmitting an electromagnetic signal is accomplished by transmitting an electromagnetic signal having a substantially square shape.

23. A method as claimed in claim 21, characterised in that said step of transmitting an electromagnetic signal is accomplished by transmitting a signal at a frequency of between fifteen and nineteen megahertz.

24. A method as claimed in claim 23, characterised in that said electromagnetic signal has a frequency substantially equal to sixteen megahertz.

25. A method as claimed in claim 23, characterised in that said electromagnetic signal has a frequency substantially equal to eighteen megahertz.

26. A method as claimed in claim 20, characterised in that said steps of transmitting and receiving said signal includes the step of inserting two conductive prongs into the test sample, wherein one of said prongs is operable for transmitting said signal into the test sample and the other one of said prongs is operable for receiving said signal from the test sample.

27. A method as claimed in claim 20, characterised in that said step of detecting the distortion of the waveform shape of said electromagnetic signal includes the steps of generating a reference signal having a periodic waveform by combining said transmitted and received electromagnetic signals, and generating an output signal related to the concentration of the chemical in the test sample by multiplying the voltage differential between said transmitted and reference electromagnetic signals by the voltage difference between said received electromagnetic signal and said reference signal.

28. A method as claimed in claim 27, characterised in that said step of generating a reference signal includes the step of combining said transmitted and received signals in a capacitor and resistor network.

29. A method as claimed in claim 20, characterised by the step of displaying the result of detecting the magnitude of the transformation of said signal as an indication of the concentration of the chemical in the test sample.

30. A method of tuning an apparatus as claimed in claim 1, characterised by inserting the two antenna probes

of the apparatus of claim 1 into a test sample containing a representative amount of the chemical, monitoring the amount of distortion of the waveform shape of the received electromagnetic signal with respect to the transmitted electromagnetic signal while varying the frequency of the transmitted electromagnetic signal through a range of frequencies, selecting for use as the frequency of the transmitted electromagnetic signal in using the apparatus to measure the concentration of the chemical that frequency which causes the greatest amount of distortion of the waveform shape of the signal due to the presence of the chemical in the test sample, and monitoring the amount of distortion of the waveform shape of the received electromagnetic signal with respect to the transmitted electromagnetic signal while varying the waveform shape of the transmitted electromagnetic signal, and selecting for use as the waveform shape of the transmitted electromagnetic signal in using the apparatus to measure the concentration of the chemical that waveform shape which causes the greatest amount of distortion of waveform shape of the electromagnetic signal due to the presence of the chemical in the test sample.

31. A method as claimed in claim 30, wherein said detector includes a capacitor and resistor network for generating a reference signal having a periodic waveform by combining the transmitted and received signals, and includes a signal processor coupled to receive the transmitted, received, and reference signals for generating an output signal related to the concentration of the chemical in the test sample by multiplying the voltage differential between the transmitted and reference signals by the voltage differential between the received and reference signals, said method of tuning the apparatus further includes the steps of monitoring the amount of distortion of the received signal with respect to the reference signal and the amount of distortion of the reference signal with respect to the transmitted signal while varying the component values of the capacitor and resistor network, and selecting for use as the component values those component values which maximize the product of the distortion of the received signal with respect to the reference signal and the distortion of the reference signal with respect to the transmitted signal due to the presence of the chemical in the test sample.

32. A method as claimed in claim 30, wherein said detector includes a capacitor and resistor network for generating a reference signal having a periodic waveform by combining the transmitted and received signals, and includes a signal processor coupled to receive the transmitted, received, and reference signals for generating an output signal related to the concentration of the chemical in the test sample by multiplying the voltage differential between the transmitted and reference signals by the voltage differential between the received and reference signals, said method of tuning the apparatus further includes the steps of monitoring the magnitude of the output signal while varying the component values of the capacitor and resistor network, and selecting those component values which maximize the output signal due to the presence of the chemical in the test sample.

Patentansprüche

1. Vorrichtung zum Messen der Konzentration einer Chemikalie in einer Testprobe, welche Vorrichtung umfaßt:
ein Wellenformgeneratormittel zum Erzeugen eines Wechselstromsignals mit periodischer nichtsinusartiger Wellenform,
eine erste Antennensonde, die mit dem Wellenformgeneratormittel zum Senden des Signals als elektromagnetisches Signal in die Testprobe wechselstromgekoppelt ist, eine zweite Antennensonde zum Empfang eines entsprechenden periodischen elektromagnetischen Signals aus der Testprobe mit Abstand von der ersten Antennensonde,
ein Detektormittel, das mit der zweiten Antennensonde zur Erfassung des empfangenen Signals wechselstromgekoppelt ist, das mit dem Wellenformgeneratormittel zur Erfassung des gesendeten Signals wechselstromgekoppelt ist und das die Verzerrung der Wellenformgestalt des empfangenen Signals bezüglich der Wellenformgestalt des erzeugten Wechselstromsignals quantifiziert, wobei sich die Stärke der Verzerrung auf die Konzentration der Chemikalie in der Testprobe bezieht.

2. Vorrichtung nach Anspruch 1,
dadurch gekennzeichnet,
daß der Detektor (18) ferner die quantifizierte Verzerrung mit einer Konzentration der Chemikalie in der Probe korreliert.

3. Vorrichtung nach Anspruch 2,
dadurch gekennzeichnet,
daß das Eingangssignal im wesentlichen eine Rechteckwellenform hat.

4. Vorrichtung nach Anspruch 1,
dadurch gekennzeichnet,
daß der Detektor (18) zur Erfassung eines Ausgangssignals mit einer Mehrzahl gleichzeitig vorhandener Frequenzen ausgebildet ist und das Ausgangssignal mit dem Eingangssignal vergleicht, ohne das Ausgangssignal in seine Teilfrequenzen zu trennen.

5. Vorrichtung nach Anspruch 2,
dadurch gekennzeichnet,
daß der Generator (12) ein Eingangssignal mit einer Frequenz von zwischen 15 und 19 Megahertz erzeugt.

6. Vorrichtung nach Anspruch 5,
dadurch gekennzeichnet,
daß das Eingangssignal eine Frequenz mit im wesentlichen gleich 16 Megahertz hat.

7. Vorrichtung nach Anspruch 5,
dadurch gekennzeichnet,
daß das Eingangssignal eine Frequenz gleich im wesentlichen 18 Megahertz hat.

8. Vorrichtung nach Anspruch 1,
dadurch gekennzeichnet,
daß die zwei Antennensonden zwei leitfähige Gabelzinken (14, 16) aufweisen, die von einem Gehäuse vorstehen, wobei einer der Gabelzinken zur Kopplung des Eingangssignals mit der Testprobe betreibbar ist und der andere der Gabelzinken zur Kopplung der Sonde mit der Testprobe zum Empfang des Ausgangssignals aus der Testprobe betreibbar ist.

9. Vorrichtung nach Anspruch 8,
dadurch gekennzeichnet,
daß die Gabelzinken (14, 16) zum Einsetzen in die Testprobe zur Kopplung mit dieser ausgebildet sind und im wesentlichen parallel angeordnet sind.

10. Vorrichtung nach Anspruch 9,
dadurch gekennzeichnet,
daß jeder der Gabelzinken eine allgemein zylindrische Gestalt hat und ein starres Ende (26) aufweist, das von dem Gehäuse vorsteht, wobei die Gabelzinken ferner mit einem hohlen Hohlraum (30) ausgebildet sind, der dem starren Ende entgegengesetzt angeordnet ist, um einen elektrischen Leiter (32) zum Anschluß an den Wellenformgenerator und den Detektor aufzunehmen.

11. Vorrichtung nach Anspruch 8,
dadurch gekennzeichnet,
daß die Spitze des starren Endes jedes der Gabelzinken vollständig abgerundet ist.

12. Vorrichtung nach Anspruch 1,
dadurch gekennzeichnet,
daß der Detektor eine Summiervorrichtung (44, 48, 50, 52) zum Erzeugen eines Bezugssignals mit einer periodischen Wellenform durch Kombinieren des Eingangssignals und des Ausgangssignals aufweist und wobei der Detektor (18) einen Signalprozessor (20) aufweist, der zum Empfang des Eingangssignals, des Ausgangssignals und des Bezugssignals gekoppelt ist, um ein Signal zu erzeugen, das sich auf die Konzentration der Chemikalie in der Testprobe bezieht, durch Multiplizieren der Spannungsdifferenz zwischen dem Eingangssignal und dem Bezugssignal mit der Spannungsdifferenz zwischen dem Ausgangssignal und dem Bezugssignal.

13. Vorrichtung nach Anspruch 12,
dadurch gekennzeichnet,

daß die Summiervorrichtung ein Kondensator- (52) und Widerstandsnetzwerk (44, 48, 50) aufweist, das zum Empfang des Eingangssignals und des Ausgangssignals gekoppelt ist.

14. Vorrichtung nach Anspruch 13,
dadurch gekennzeichnet,
daß das Eingangssignal von dem Wellenformgenerator einem ersten Anschluß des Signalprozessors und dem Kondensator- und Widerstandnetzwerk zugeführt wird, und wobei das Ausgangssignal von der zweiten Antennensonde einem zweiten Anschluß des Signalprozessors und dem Kondensator- und Widerstandsnetzwerk zugeführt wird.

15. Vorrichtung nach Anspruch 14,
dadurch gekennzeichnet,
daß das Kondensator- und Widerstandsnetzwerk aufweist: einen ersten Widerstand (44), der zwischen dem ersten Anschluß (Y-Eingang) des Signalprozessors und einem Masseknoten (46) gekoppelt ist, einen zweiten Widerstand (48), der zwischen dem zweiten Anschluß (X-Eingang) des Signalprozessors und dem Masseknoten gekoppelt ist, und einen dritten Widerstand (50) und einen Kondensator (52), die parallel zwischen dem Masseknoten und einem dritten (gemeinsamen) Anschluß des Signalprozessors gekoppelt sind.

16. Vorrichtung nach Anspruch 15,
dadurch gekennzeichnet,
daß der Signalprozessor einen Analogmultiplizierer (34) aufweist, der das Produkt der über den ersten und dritten Anschlüssen angelegten Spannung und der über den zweiten und dritten Anschlüssen angelegten Spannung bildet, und einen Kondensator (54) aufweist, der zwischen einem Ausgangsanschluß des Analogmultiplizierers und Masse gekoppelt ist, wodurch der Ausgangsanschluß ein Gleichstromsignal erzeugt, das sich auf die Konzentration der Chemikalie in der Testprobe bezieht.

17. Vorrichtung nach Anspruch 12,
dadurch gekennzeichnet,
daß der Detektor ferner einen Ausgang aufweist, der auf das auf die Konzentration der Chemikalie bezogene Signal anspricht, um einen Hinweis auf die Konzentration der Chemikalie in der Testprobe anzuzeigen.

18. Vorrichtung nach Anspruch 1,
dadurch gekennzeichnet,
daß der Wellenformgenerator (36) von der ersten Antennensonde durch einen Kondensator (40) isoliert ist, um den Fluß von Gleichstrom durch die Testprobe zu verhindern.

19. Vorrichtung nach Anspruch 1,
dadurch gekennzeichnet,
daß der Detektor von der zweiten Antennensonde durch einen Kondensator (42) isoliert ist, um den Fluß von Gleichstrom durch die Testprobe zu verhindern.

20. Verfahren zum Messen der Konzentration einer Chemikalie in einer Testprobe, wobei das Verfahren die Schritte aufweist:
Erzeugen eines Wechselstromsignals mit periodischer nicht sinusartiger Wellenform,
Senden des Signals als elektromagnetisches Signal in die Testprobe mittels einer ersten Antennensonde,
Empfangen eines entsprechenden elektromagnetischen Signals von der Testprobe mittels einer zweiten Antennensonde mit Abstand von der ersten Antennensonde,
Erfassen des empfangenen Signals und auch des erzeugten Wechselstromsignals und Quantifizieren der Verzerrung der Wellenformgestalt des empfangenen Signals bezüglich der Wellenformgestalt des erzeugten Wechselstromsignals, wobei die Stärke der Verzerrung auf die Konzentration der Chemikalie in der Testprobe bezogen wird.

21. Verfahren nach Anspruch 20,
dadurch gekennzeichnet,
daß vor dem Schritt des Sendens eines elektromagnetischen Signals ein elektromagnetisches Signal erzeugt wird, dessen Gestalt und Frequenz bezüglich der zu messenden Chemikalie gewählt ist, um die

Stärke der Verzerrung zu verbessern, und das Signal während des Sendeschritts verwendet wird.

22. Verfahren nach Anspruch 20,
dadurch gekennzeichnet,
daß der Schritt des Sendens eines elektromagnetischen Signals durch Senden eines elektromagnetischen Signals mit im wesentlichen einer Rechteckform durchgeführt wird.

23. Verfahren nach Anspruch 21,
dadurch gekennzeichnet,
daß der Schritt des Sendens eines elektromagnetischen Signals durch Senden eines Signals mit einer Frequenz von zwischen 15 und 19 Megahertz durchgeführt wird.

24. Verfahren nach Anspruch 23,
dadurch gekennzeichnet,
daß das elektromagnetische Signal eine Frequenz im wesentlichen gleich 16 Megahertz aufweist.

25. Verfahren nach Anspruch 23,
dadurch gekennzeichnet,
daß das elektromagnetische Signal eine Frequenz im wesentlichen gleich 18 Megahertz aufweist.

26. Verfahren nach Anspruch 20,
dadurch gekennzeichnet,
daß die Schritte des Sendens und des Empfangs des Signals den Schritt enthalten, zwei leitfähige Gabelzinken in die Testprobe einzusetzen, wobei einer der Gabelzinken zum Senden des Signals in die Testprobe betreibbar ist und der andere der Gabelzinken zum Empfang des Signals aus der Testprobe betreibbar ist.

27. Verfahren nach Anspruch 20,
dadurch gekennzeichnet,
daß der Schritt der Erfassung der Verzerrung der Wellenformgestalt des elektromagnetischen Signals die Schritte umfaßt: Erzeugen eines Bezugssignals mit periodischer Wellenform durch Kombination der gesendeten und empfangenen elektromagnetischen Signale, und Erzeugen eines Ausgangssignals, das sich auf die Konzentration der Chemikalie in der Testprobe bezieht, durch Multiplizieren der Spannungsdifferenz zwischen den elektromagnetischen Sende- und Bezugssignalen mit der Spannungsdifferenz zwischen dem empfangenen elektromagnetischen Signal und dem Bezugssignal.

28. Verfahren nach Anspruch 27,
dadurch gekennzeichnet,
daß der Schritt des Erzeugens eines Bezugssignals den Schritt umfaßt, die gesendeten und empfangenen Signale in einem Kondensator- und Widerstandsnetzwerk zu kombinieren.

29. Verfahren nach Anspruch 20,
dadurch gekennzeichnet,
den Schritt des Anzeigens des Ergebnisses der Erfassung der Stärke der Wandlung des Signals als Hinweis der Konzentration der Chemikalie in der Testprobe.

30. Verfahren zum Abstimmen einer Vorrichtung nach Anspruch 1,
gekennzeichnet durch
Einsetzen der zwei Antennensonden der Vorrichtung nach Anspruch 1 in eine Testprobe, die eine repräsentative Menge der Chemikalie enthält, Überwachen des Betrags der Verzerrung der Wellenformgestalt des empfangenen elektromagnetischen Signals bezüglich des gesendeten elektromagnetischen Signals während Veränderung der Frequenz des gesendeten elektromagnetischen Signals durch einen Bereich von Frequenzen, Wählen, zur Verwendung als die Frequenz des gesendeten elektromagnetischen Signals bei Verwendung der Vorrichtung zum Messen der Konzentration der Chemikalie, derjenigen Frequenz, die den größten Betrag der Verzerrung der Wellenformgestalt des Signals aufgrund der Gegenwart der Chemikalie in der Testprobe verursacht, und Überwachen des Betrags der Verzerrung der Wellenformgestalt des empfangenen elektromagnetischen Signals bezüglich des gesendeten elektromagnetischen Signals während Veränderung der Wellenformgestalt des gesendeten elektromagnetischen Si-

gnals, und Wählen, zur Verwendung als die Wellenformgestalt des gesendeten elektromagnetischen Signals bei der Verwendung der Vorrichtung zum Messen der Konzentration der Chemikalie, derjenigen Wellenformgestalt, die den größten Betrag der Verzerrung der Wellenformgestalt des elektromagnetischen Signals aufgrund der Gegenwart der Chemikalie in der Testprobe verursacht.

31. Verfahren nach Anspruch 30, in dem der Detektor ein Kondensator- und Widerstandsnetzwerk zum Erzeugen eines Bezugssignals mit periodischer Wellenform durch Kombiantion der gesendeten und empfangenen Signale aufweist, und einen Signalprozessor aufweist, der zum Empfang der gesendeten, empfangenen und Bezugssignale zum Erzeugen eines Ausgangssignals gekoppelt ist, das sich auf die Konzentration der Chemikalie in der Testprobe bezieht, durch Multiplizieren der Spannungsdifferenz zwischen den Sende- und Empfangssignalen mit der Spannungsdifferenz zwischen den Empfangs- und Bezugssignalen, wobei das Verfahren der Abstimmung der Vorrichtung ferner die Schritte umfaßt: Überwachen des Betrags der Verzerrung des empfangenen Signals bezüglich des Bezugssignals und des Betrags der Verzerrung des Bezugssignals bezüglich des gesendeten Signals während Veränderung der Komponentenwerte des Kondensator- und Widerstandsnetzwerks, und Wählen, zur Verwendung als die Komponentenwerte, derjenigen Komponentenwerte, die das Produkt der Verzerrung des empfangenen Signals bezüglich des Bezugssignals und der Verzerrung des Bezugssignals bezüglich des gesendeten Signals aufgrund der Gegenwart der Chemikalie in der Testprobe maximieren.

32. Verfahren nach Anspruch 30, in dem der Detektor ein Kondensator- und Widerstandsnetzwerk zum Erzeugen eines Bezugssignals mit periodischer Wellenform durch Kombinieren der gesendeten und empfangenen Signale aufweist, und einen Signalprozessor aufweist, der zum Empfang der gesendeten, empfangenen und Bezugssignale zum Erzeugen eines Ausgangssignals gekoppelt ist, das sich auf die Konzentration der Chemikalie in der Testprobe bezieht, durch Multiplizieren der Spannungsdifferenz zwischen den Sende- und Bezugssignalen mit der Spannungsdifferenz zwischen den Empfangs- und Bezugssignalen, wobei das Verfahren der Abstimmung der Vorrichtung ferner die Schritte umfaßt: Überwachen der Stärke des Ausgangssignals während Veränderung der Komponentenwerte des Kondensator- und Widerstandsnetzwerks, und Wählen derjenigen Komponentenwerte, die das Ausgangssignal aufgrund der Gegenwart der Chemikalie in der Testprobe maximieren.

Revendications

1. Appareil pour mesurer la concentration d'un produit chimique dans un échantillon d'essai, ledit appareil comprenant :

   un moyen de création d'une forme d'onde pour générer un signal <u>en courant alternatif (ca)</u> ayant une forme d'onde périodique <u>non sinusoïdale</u>

   une <u>première</u> antenne à couplage alternatif avec ledit moyen de création de forme d'onde pour transmettre ledit signal <u>comme un signal électromagnétique</u> dans l'échantillon d'essai,

   une <u>seconde antenne</u> de couplage pour recevoir un signal <u>électromagnétique</u> périodique correspondant venant de l'échantillon d'essai <u>éloignée de la première antenne</u> ,

   un moyen de détection qui est <u>à couplage alternatif avec la seconde antenne</u> afin de détecter le signal reçu, lequel est <u>à couplage alternatif avec le moyen de création de la forme d'onde</u> afin de détecter le signal lorsqu'émis et qui quantifie <u>la déformation</u> de la configuration de forme d'onde dudit signal reçu par rapport à la configuration de la forme d'onde <u>dudit signal en courant alternatif produit</u>, dans lequel l'amplitude de la <u>déformation</u> est rapportée à la concentration du produit chimique dans l'échantillon d'essai.

2. Appareil selon la revendication 1, caractérisé en ce que ledit détecteur (18) corrèle de plus la déformation quantifiée à une concentration du produit chimique dans l'échantillon.

3. Appareil selon la revendication 2, caractérisé en ce que ledit signal d'entrée présente une forme d'onde carrée.

4. Appareil selon la revendication 1, caractérisé en ce que ledit détecteur (18) est formé pour détecter un signal de sortie comportant une pluralité de fréquences présentes simultanément et compare ledit signal de sortie audit signal d'entrée sans séparer ledit signal de sortie en ses fréquences composantes.

5. Appareil selon la revendication 2, caractérisé en ce que ledit générateur (12) produit un signal d'entrée ayant une fréquence comprise entre quinze et dix neuf mégahertz.

6. Appareil selon la revendication 5, caractérisé en ce que ledit signal d'entrée possède une fréquence sensiblement égale à seize mégahertz.

7. Appareil selon la revendication 5, caractérisé en ce que ledit signal d'entrée possède une fréquence sensiblement égale à dix huit mégahertz.

8. Appareil selon la revendication 1, caractérisé en ce que lesdites deux antennes de couplage comprennent deux broches conductrices (14, 16) faisant saillie à partir d'une enceinte, dans laquelle l'une desdites broche peut agir pour coupler ledit signal d'entrée avec l'échantillon d'essai et l'autre desdites broches peut agir pour coupler ladite antenne audit échantillon d'essai en vue de recevoir ledit signal de sortie venant de l'échantillon d'essai.

9. Appareil selon la revendication 8, caractérisé en ce que lesdites broches (14,16) sont formées pour une insertion dans ledit échantillon d'essai pour lui être couplées et sont disposées sensiblement de façon parallèle.

10. Appareil selon la revendication 9, caractérisé en ce que chacune desdites broches est généralement de forme cylindrique et comprend une extrémité solide (26) qui fait saillie à partir de ladite enceinte, lesdites broches étant, de plus, formées avec une cavité creuse (30) disposée à l'opposé de ladite extrémité solide pour recevoir un conducteur électrique (32) afin de les connecter audit générateur de forme d'onde et audit détecteur.

11. Appareil selon la revendication 8, caractérisé en ce que la pointe de ladite extrémité solide de chacune desdites broches est totalement curviligne.

12. Appareil selon la revendication 1, caractérisé en ce que ledit détecteur comprend un dispositif additionneur (44, 48, 50, 52) pour générer un signal de référence ayant une forme d'onde périodique en combinant ledit signal d'entrée et ledit signal de sortie et ledit détecteur (18) comprend un processeur de signal (20) couplé pour recevoir ledit signal d'entrée, ledit signal de sortie et ledit signal de référence pour générer un signal relié à la concentration du produit chimique dans l'échantillon d'essai en multipliant le différentiel de tension entre ledit signal d'entrée et ledit signal de référence par le différentiel de tension entre ledit signal de sortie et ledit signal de référence.

13. Appareil selon la revendication 12, caractérisé en ce que ledit dispositif additionneur comprend un condensateur (52) et un réseau de résistances (44, 48, 50) couplés pour recevoir ledit signal d'entrée et ledit signal de sortie.

14. Appareil selon la revendication 13, caractérisé en ce que ledit signal d'entrée est fourni à une première borne dudit processeur de signal et audit condensateur et audit réseau de résistances à partir du générateur de forme d'onde et dans lequel ledit signal de sortie est fourni à une seconde borne dudit processeur de signal et audit condensateur et réseau de résistances à partir de ladite seconde antenne de couplage.

15. Appareil selon la revendication 14, caractérisé en ce que ledit réseau de condensateur et de résistances comprend une première résistance (44) couplée entre ladite première borne (entrée Y) dudit processeur de signal et un noeud mis à la terre (46), une seconde résistance (48) couplée entre ladite seconde borne (entrée X) dudit processeur de signal et ledit noeud mis à la terre et une troisième résistance (50) et un condensateur (52) couplés en parallèle entre ledit noeud mis à la terre et une troisième borne (commun) dudit processeur de signal.

16. Appareil selon la revendication 15, caractérisé en ce que ledit processeur de signal comprend un multiplieur analogique (34) qui forme le produit de la tension appliquée à travers lesdites première et troisième bornes et de la tension appliquée à travers lesdites seconde et troisième bornes et comprend un condensateur (54) couplé entre une borne de sortie dudit multiplieur analogique et la terre, de sorte que ladite borne de sortie génère un signal en courant continu qui est relié à la concentration du produit chimique dans l'échantillon d'essai.

17. Appareil selon la revendication 12, caractérisé en ce que ledit détecteur comprend de plus une sortie sensible audit signal relié à la concentration du produit chimique pour afficher une indication de la concentration du produit chimique dans l'échantillon de test.

18. Appareil selon la revendication 1, caractérisé en ce que ledit générateur de la forme d'onde (36) est isolé de ladite première antenne de couplage par un condensateur (40) pour empêcher le courant continu de circuler à travers l'échantillon d'essai.

19. Appareil selon la revendication 1, caractérisé en ce que ledit détecteur est isolé de ladite seconde antenne de couplage par un condensateur (42) pour empêcher le courant continu de circuler à travers l'échantillon d'essai.

20. Procédé pour mesurer la concentration d'un produit chimique dans un échantillon d'essai, ledit procédé comprenant les étapes consistant à :
générer un signal ca ayant une forme d'onde périodique non sinusoïdale,
transmettre ledit signal comme un signal électromagnétique dans l'échantillon d'essai par l'intermédiaire d'une première antenne de couplage,
recevoir un signal électromagnétique correspondant issu de l'échantillon d'essai par l'intermédiaire d'une seconde antenne de couplage éloignée de la première antenne,
détecter le signal reçu et également le signal en courant alternatif produit et quantifier la déformation de la configuration de forme d'onde dudit signal reçu par rapport à la configuration de forme d'onde dudit signal en courant alternatif produit, de façon que l'amplitude de la déformation soit reliée à la concentration du produit chimique dans l'échantillon d'essai.

21. Procédé selon la revendication 20, caractérisé en ce qu' avant ladite étape consistant à transmettre un signal électromagnétique, un signal électromagnétique est produit présentant une configuration et une fréquence électionnées en référence au produit chimique à mesurer afin d'augmenter l'amplitude de la déformation et ledit signal est utilisé pendant ladite étape d'émission.

22. Procédé selon la revendication 20, caractérisé en ce que ladite étape d'émission d'un signal électromagnétique est réalisée en émettant un signal présentant une forme sensiblement carrée.

23. Procédé selon la revendication 21, caractérisé en ce que ladite étape consistant à émettre un signal électromagnétique est réalisée en émettant un signal à une fréquence comprise entre quinze et dix neuf mégahertz.

24. Procédé selon la revendication 23 caractérisé en ce que ledit signal électromagnétique possède une fréquence sensiblement égale à seize mégahertz.

25. Procédé selon la revendication 23, caractérisé en ce que ledit signal électromagnétique possède une fréquence sensiblement égale à dix huit mégahertz.

26. Procédé selon la revendication 20, caractérisé en ce que lesdites étapes consistant à émettre et à recevoir ledit signal comprennent l'étape consistant à insérer deux broches conductrices dans l'échantillon d'essai, dans lequel l'une des broches peut agir pour transmettre ledit signal dans l'échantillon d'essai et l'autre desdites broches peut agir pour recevoir ledit signal issu de l'échantillon d'essai.

27. Procédé selon la revendication 20, caractérisé en ce que ladite étape consistant à détecter la déformation de la configuration de forme d'onde dudit signal électromagnétique inclut les étapes consistant à produire un signal de référence ayant une forme d'onde périodique en combinant lesdits signaux électromagnétiques émis et reçus et en produisant un signal de sortie relié à la concentration du produit chimique dans l'échantillon d'essai en multipliant le différentiel de tension entre lesdits signaux électromagnétiques émis et de référence par la différence de tension entre ledit signal électromagnétique reçu et ledit signal de référence.

28. Procédé selon la revendication 27, caractérisé en ce que ladite étape consistant à produire un signal de référence comprend l'étape consistant à combiner lesdits signaux émis et reçus dans un réseau de condensateur et de résistances.

29. Procédé selon la revendication 20, caractérisé par l'étape consistant à afficher le résultat de la détection de l'amplitude de la transformation dudit signal comme une indication de la concentration du produit chimique dans l'échantillon d'essai.

30. Procédé consistant à régler un appareil selon la revendication 1, caractérisé par le fait d'insérer les deux antennes de l'appareil selon la revendication 1 dans un échantillon d'essai contenant une quantité représentative du produit chimique, de contrôler la quantité de déformation de la configuration de forme d'onde du signal électromagnétique reçu par rapport au signal électromagnétique émis tout en faisant varier la fréquence du signal électromagnétique émis à travers une plage de fréquences, de choisir pour l'utiliser comme la fréquence du signal électromagnétique émis en utilisant l'appareil pour mesurer la concentration du produit chimique, cette fréquence qui entraine la quantité de déformation la plus grande de la configuration de forme d'onde du signal en raison de la présence du produit chimique dans l'échantillon d'essai, et de surveiller la quantité de déformation de la configuration de forme d'onde du signal électromagnétique reçu par rapport au signal électromagnétique émis tout en modifiant la configuration de forme d'onde du signal électromagnétique émis , et de sélectionner pour l'utiliser comme configuration de forme d'onde du signal électromagnétique émis en utilisant l'appareil pour mesurer la concentration du produit chimique cette configuration de forme d'onde qui entraine la quantité la plus grande de déformation de la configuration de forme d'onde du signal électromagnétique en raison de la présence du produit chimique dans l'échantillon d'essai.

31. Procédé selon la revendication 30, dans lequel ledit détecteur comprend un réseau de condensateurs et de résistances pour produire un signal de référence ayant une forme d'onde périodique en combinant les signaux émis et les signaux reçus, et comprend un processeur de signal couplé pour recevoir les signaux émis, reçus et de référence pour générer un signal de sortie reliés à la concentration du poduit chimique dans l'échantillon d'essai en multipliant le différentiel de tension entre les signaux émis et de référence par le différentiel de tension entre les signaux reçus et de référence, ledit procédé de réglage de l'appareil comprend, de plus, les étapes consistant à contrôler la quantité de déformation du signal reçu par rapport au signal de référence et la quantité de déformation du signal de référence par rapport au signal émis tout en faisant varier les valeurs des composants du réseau de condensateurs et de résistances et à sélectionner pour les utiliser comme valeurs de composants ces valeurs de composants qui rendent maximale le produit de la déformation du signal reçu par rapport au signal de référence et de la déformation du signal de référence par rapport au signal émis en raison de la présence du produit chimique dans ledit échantillon d'essai.

32. Procédé selon la revendication 30, dans lequel ledit détecteur comprend un réseau de condensateur et de résistances destiné à produire un signal de référence ayant une forme d'onde périodique en combinant les signaux émis et reçus et comprend un processeur de signal couplé pour recevoir les signaux émis, reçus et de référence pour générer un signal de sortie relié à la concentration du produit chimique dans l'échantillon d'essai en multipliant le différentiel de tension entre les signaux émis et de référence par le différentiel de tension entre les signaux reçus et de référence, ledit procédé de réglage de l'appareil comprenant de plus les étapes consistant à surveiller l'amplitude du signal de sortie tout en modifiant les valeurs des composants du réseau des condensateurs et résistances et à sélectionner ces valeurs des composants qui rendent maximal le signal de sortie en raison de la présence du produit chimique dans l'échantillon d'essai.

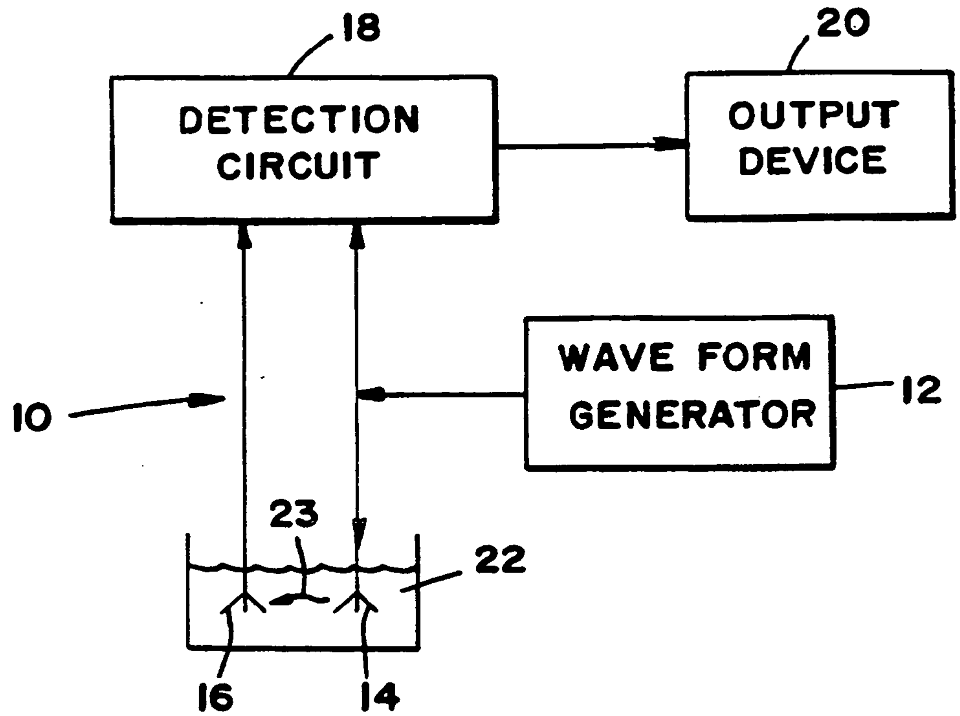

18
20
DETECTION CIRCUIT
OUTPUT DEVICE
WAVE FORM GENERATOR
10
12
23
22
16
14

FIG_1

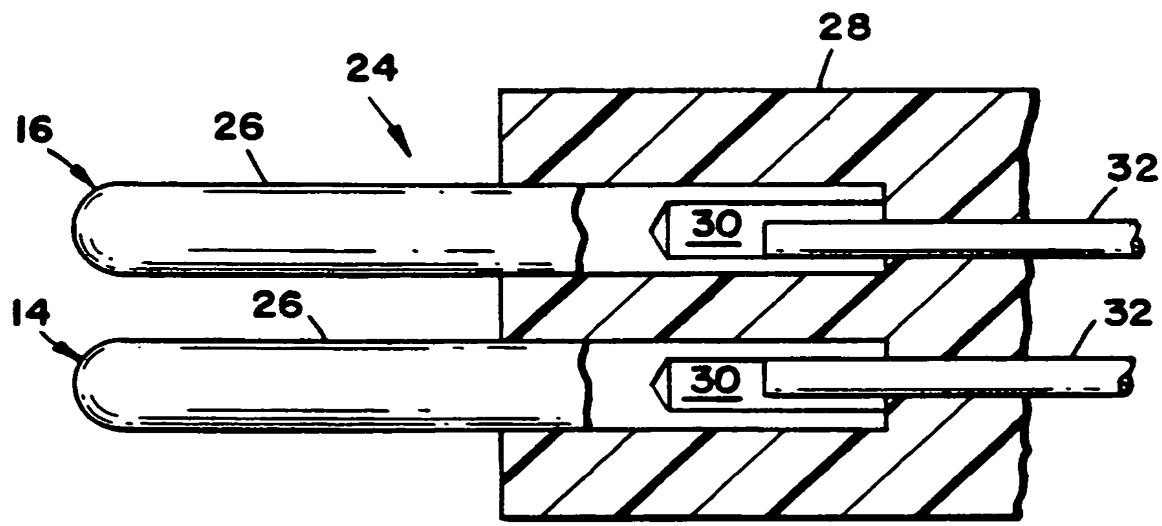

28
24
16
26
30
32
14
26
30
32

FIG_2

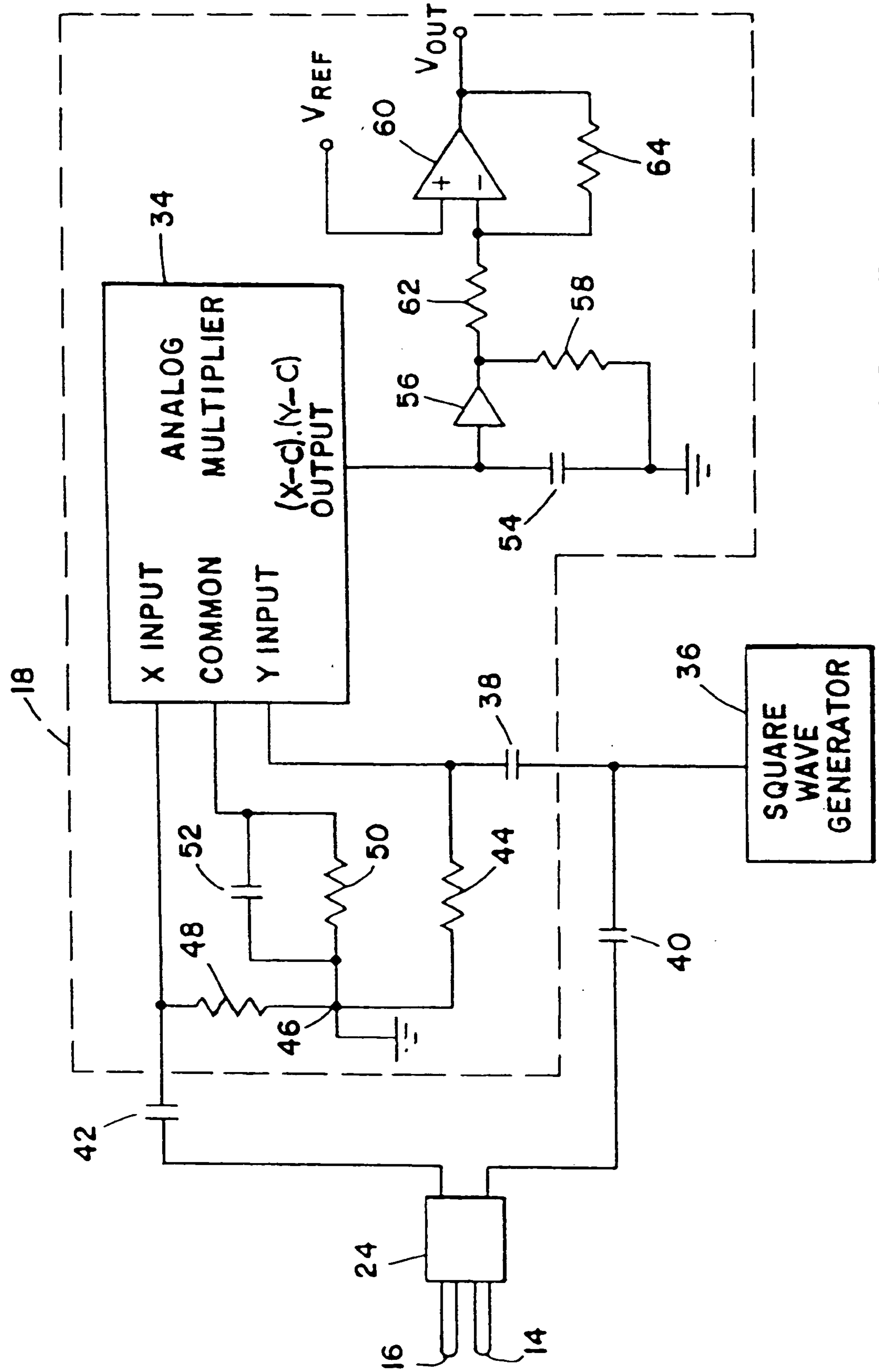
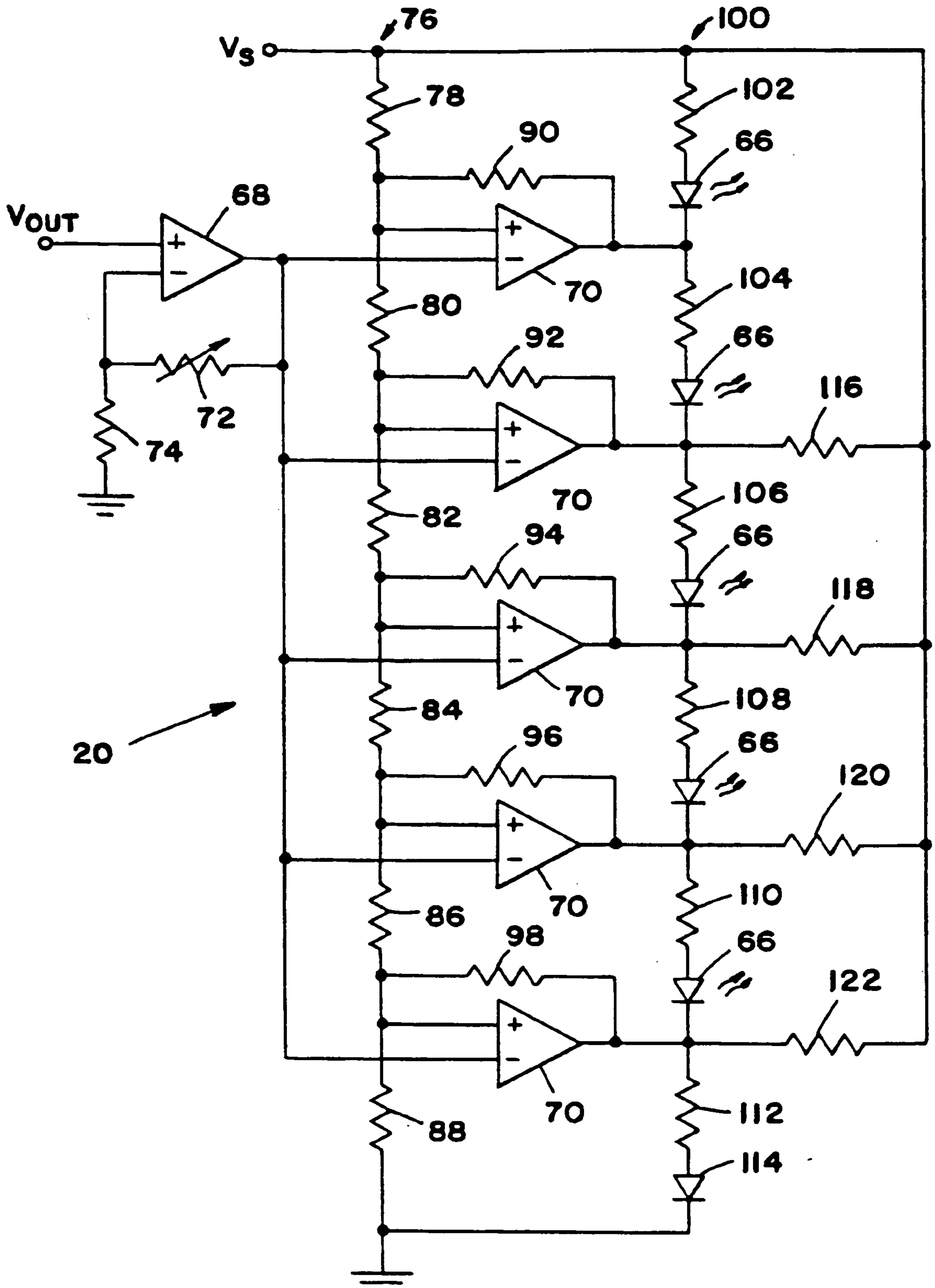

ANALOG MULTIPLIER
X INPUT
COMMON
Y INPUT
(X–C).(Y–C) OUTPUT
SQUARE WAVE GENERATOR
V_{REF}
V_{OUT}
18
34
36
38
40
42
44
46
48
50
52
54
56
58
60
62
64
24
16
14

FIG_3



76
100
V_S
78
102
90
66
68
V_{OUT}
70
104
80
92
66
116
72
74
70
106
82
94
66
118
70
108
84
20
96
66
120
70
110
86
98
66
122
70
112
88
114

FIG_4

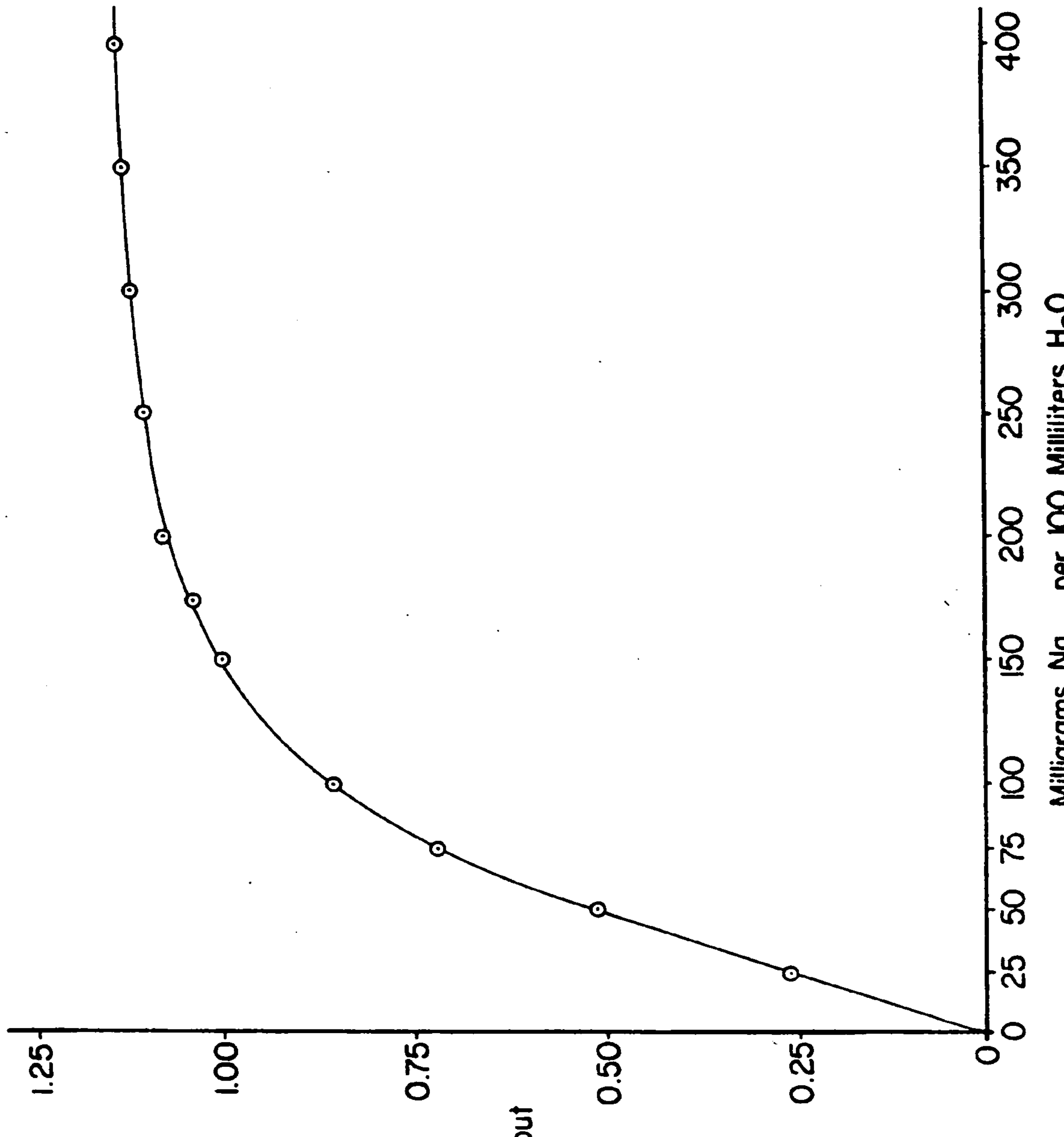

VOLTAGE in VOLTS
(Between X·Y Output
and V_{REF})
1.25
1.00
0.75
0.50
0.25
0
25
50
75
100
150
200
250
300
350
400
Milligrams Na per 100 Milliliters H_2O

FIG_5